Imaging Across the Spectrum: Synergies Between SKA and Other Future Telescopes

Andrei Lobanov

Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany

Abstract. SKA[1] will be operating at the same time with several new large optical, X–ray and Γ–ray facilities currently under construction or planned. Fostering synergies in astrophysical research made across different spectral bands presents a compelling argument for designing the SKA such that it would offer imaging capabilities similar to those of other future telescopes. Imaging capabilities of the SKA are compared here with those of the major future astrophysical facilities.

1 Imaging performance of SKA and other future telescopes

A first order comparison of imaging performance of different instruments can be made by comparing their respective spatial dynamic ranges (SDR, the ratio between the maximum and the minimum detectable angular scales) and resolutions.

The resolution of the SKA is compared in Figure 1 with the resolutions of various existing and future telescopes. The resolution of SKA is close to the resolution of the largest projected optical telescopes, but it may be inferior to the resolution of the proposed X–ray interferometer mission MAXIM. For the optical telescopes, the SKA would be able to present a reasonable match provided that the SKA reaches a ≤ 1 mas resolution at its highest observing frequency (see [1] for more details).

The SDR of the different SKA designs is compared in Figure 1 with the SDR of other instruments. For a radio interferometer, the SDR is affected by the observing bandwidth, $\Delta\nu$, averaging time, τ, and filling factor of the Fourier domain, $\Delta u/u$ [1] (analogies of these quantities can be found for all instruments working in other spectral bands).

For most of the high–dynamic range observations with the SKA the bandwidth and integration time may have to be significantly reduced, if one would require to reach SDR similar to that of the largest optical instruments. These two corrections can be introduced at the stage of observation preparation, and their worst effect is the increased observing time needed to reach the required sensitivity. The Fourier space sampling, described by the $\Delta u/u$ ratio, is however "hard–wired" into the array design, and can only be improved by adding new

[1] The Square Kilometer Array, a next generation interferometric instrument for centimeter-wave radio astronomy. See http://www.skatelescope.org for a detailed description.

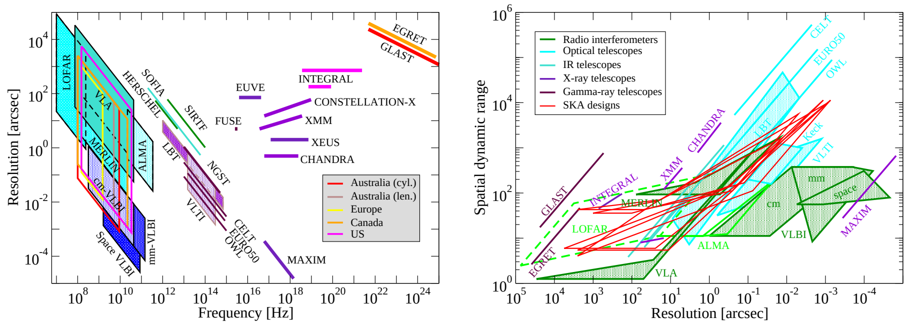

Fig. 1. Left: Resolution of the SKA compared with the resolution of other main existing and future astronomical instruments. **Right:** Spatial dynamic range of the SKA designs for observations with $\Delta\nu$=1 MHz and τ=1 s) compared to other major instruments [1].

stations. For an inhomogeneous array in which $\Delta u/u$ varies depending on the baseline length, the reduction of spatial and even conventional dynamic range may be substantial. This dictates the need to optimize this parameter at the earliest possibles stages of the array design. In addition to that, optimization of $\Delta u/u$ is also required by high–fidelity imaging at low SNR levels. The lowest SNR of "trustable" pixel in an interferometric image is given by

$$\ln(\mathrm{SNR}_{\mathrm{low}}) = \left[\frac{\pi}{4}\left(\frac{\Delta \mathrm{u}}{\mathrm{u}}+1\right)\right]^2 \frac{1}{\ln 2}\,. \tag{1}$$

The SDR reduction due to poor Fourier space sampling becomes significant at $\Delta u/u \geq 0.4$, and it is negligible at $\Delta u/u \leq 0.2$. It should therefore be possible to reach the maximum SDR levels in an array configuration that provides $\Delta u/u \leq 0.2$ at all baselines. If multifrequency synthesis is used for imaging, this condition becomes $\Delta u/u \leq 0.2 + \Delta\nu_{\mathrm{mfs}}$ ($\Delta\nu_{\mathrm{mfs}}$ is the fractional bandwidth over which the synthesis is performed). Therefore, this requirement must be considered as one of the basic requirements for the design of the SKA.

To make the SKA a competitive imaging instrument that would match the capabilities of future optical and X-ray telescopes, two basic conditions must be fulfilled:

1. Resolution of ≤ 1 mas at the highest observing frequency.
2. Fourier plane filling factor $\Delta u/u \leq 0.2$ over the entire range of uv–coverage.

References

1. A.P. Lobanov, SKA Memo No. 38 (2003)
`http://www.skatelescope.org/PDF/ska_memo38.pdf`